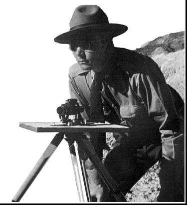
GEOLOGIC RESOURCE MONITORING PARAMETERS

Subsurface Temperature Regime



Brief Description: Temperatures in boreholes a few hundred metres deep can be an important source of information on recent climatic changes, because the normal upward heat flow from the Earth's crust and interior is perturbed by the downward propagation of heat from the surface. As temperature fluctuations are transmitted downward, they become progressively smaller, with shorter-period variations attenuating more rapidly than longer ones. Although seasonal oscillations may be undetectable below about 15 m, century-long temperature records may be observed to depths of 150 m or so. Bedrocks thus selectively retain the long-term trends required for reconstructing climate change.
The surface temperature is strongly affected by local factors such as thickness and duration of snow cover, type of vegetation, properties of organic soil layers, depth to the water table, and topography. It influences, in turn, a wide range of ground and surface processes, particularly in the near-surface portions of permafrost [see frozen ground activity]. Below the active layer, where ground temperature fluctuates seasonally as thawing and freezing take place, long-term temperature variations may be recorded. Here, repeated measurements of soil temperature at fixed locations can reveal both the long-term dynamics of seasonally frozen ground and long-term climatic fluctuations, though the conversion of ground temperature to climate history is a complex matter. In the northern Canadian prairies ground temperatures have risen by 2oC and permafrost has retreated northwards by 100 km in the past 50 years. In contrast, permafrost temperatures have fallen in northern Quebec in recent years.

Significance: The thermal regime of soils and bedrocks exercises an important control on the soil ecosystem, on near-surface chemical reactions (e.g. involving groundwater), and on the ability of these materials to sequester or release greenhouse gases. It may affect the type, productivity and decay of plants, the availability and retention of water, the rate of nutrient cycling, and the activities of soil microfauna. It is also of major importance as an archive of climate change, indicating changes in surface temperature over periods of up to 2-3 centuries, for example in regions without a record of past surface temperatures. In permafrost, the ground temperature controls the mechanical properties of the soils, especially during the freeze-thaw transition in the active layer.

Environment where Applicable: Any terrestrial area, but particularly in permafrost regions.

Types of Monitoring Sites: Remote sites no more than 500-1000 km apart and away from obvious human disturbances, bodies of surface water, or areas of high geothermal flow where the ground cover is left undisturbed. The best results are obtained from measurements in relatively impermeable bedrocks or where there has been minimal groundwater movement. To ensure a good representation of climate-induced change, measurements should be made in clusters of boreholes drilled specifically for this purpose.

Method Of Measurement: Many parameters must be measured, and many factors need to be considered when converting the signal to changes in surface temperature. Temperatures must be accurately measured (±millidegrees) in boreholes, using thermocouples, thermistors, thermoresistors and other measuring devices. Automated data loggers are most convenient for repeated measurements.

Frequency of Measurement: At least once every 5 years for deep boreholes, more frequently (as often as twice daily) for near-surface temperatures in permafrost.

Limitations of Data And Monitoring: The thermal coupling of the Earth's surface to the atmosphere is complex, and the temperature signal recorded in the near surface is a filtered version of changes in surface climate. Physical movements in the active layer of permafrost regions complicate the picture [see frozen ground activity], as do the effects of snow cover and vegetation in temperate and tropical areas, and human activities such as urbanization, agriculture or deforestation. Moreover local topography, precipitation, hydrology and vegetation can mask the downward propagation of atmospheric temperatures. The installation of bore-holes disturbs the natural temperature regime, which should be allowed to recover before monitoring begins.

Possible Thresholds: In near-surface permafrost, the freeze-thaw threshold, which may vary in temperature according to soil and water salinity, controls a wide range of surficial (periglacial) processes [see frozen ground activity].

Key References:

Lachenbruch, A.H. & B.V.Marshall 1986. Changing climate: geothermal evidence from permafrost in the Alaskan Arctic. Science 234: 689-696.

Lewis,T. (ed.), 1992. Climatic change inferred from underground temperatures. Global and Planetary Change 6:71-281.

Williams, P.J. & M.W.Smith 1989. The frozen Earth - fundamentals of geocryology. Cambridge: Cambridge University Press.

Related Environmental and Geological Issues: Climate change, groundwater flow. Changes in near-surface ground temperature may affect soil fauna and sensitive surface vegetation.

Overall Assessment: The subsurface temperature regime is a direct measure of ground temperature history. It constitutes a very important indicator of thermal change in the periglacial environment, in soils (e.g. due to past deforestation, draining of wetlands), and in climate.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.